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SIMULTANEOUS CO AND CO2 LASER

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SIMULTANEOUS CO AND CO_2 LASER

ABSTRACT OF THE DISCLOSURE

A gas laser having two different and simultaneous discharge cooling temperatures of approximately 77°K and 300°K and a premixed flowing gaseous mixture of helium, air, and carbon monoxide, with pressure ratios of approximately 21-3-1 respectively at a total pressure of approximately 10 torr, provides laser radiation from the CO molecules at approximately 5 microns wavelength and simultaneous laser radiation from the CO_2 molecules, formed in the laser tube by CO dissociation oxidation in the dc discharge, at approximately 10.6 microns wavelength.

RIGHTS OF THE GOVERNMENT

The Government of the United States has at least a nonexclusive, irrevocable, royalty-free license in the invention described herein with power to grant licenses for all governmental purposes.

BACKGROUND OF THE INVENTION

The field of the invention is in the gaseous laser art.

Prior art lasers simultaneously lasing at two different frequencies are disclosed in patent numbers 3,704,428 to patentees Barry et al and 3,772,609 to patentees Willett et al. A typical prior art room temperature CO laser is disclosed in patent number 3,761,838 to patentees Bhaumik et al. Additional discussion of this present invention may be found in the IEEE Journal of Quantum Electronics, Vol. QE-9, No. 7, July 1973 at pages 779 and 780.

SUMMARY OF THE INVENTION

The invention is a gas laser simultaneously lasing CO and CO_2 molecules providing simultaneous laser radiation at output wave-lengths in the ranges of approximately 5.2 to 5.9 µm and 9.6 to 10.6 µm respectively.

BRIEF DESCRIPTION OF THE DRAWING

The single figure in the drawing shows a schematic diagram of a typical embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the representative embodiment of the invention shown in the drawing, the gases He, air, and CO are premixed in the mixing chamber 11 and then introduced directly into the laser gas cavity. The laser gas cavity is segmented into two parts 12 and 13. Both segments are composed of conventional double-walled glass discharge tubes. In a particular embodiment, gas chamber tubes 12 and 13 have an internal diameter of approximately one inch. They are coupled together with a conventional Varian flange 14. The cooling chambers 23 and 25 have outside walls approximately four inches in diameter. Varian flanges 15 and 16 also are used to couple to the tube sections 17 and 18 which provide for the gas inlet from tube 19 and the gas outlet through tube 20. These short tube sections 17 and 18 also contain the conventional NaCl Brewster windows 21 and 22 which terminate the laser discharge tube and provide optical

transmission. In this embodiment the distance from one Brewster window to the other forms a gas cavity having a total length of approximately 251 cm. The right-hand gas tube segment 12 has a length between the Varian flanges 14 and 15 of approximately 92 cm. It is cooled by liquid nitrogen between the walls forming the chamber 22 surrounding the gas tube. The liquid nitrogen is poured into the chamber through entrance 24. The left-hand tube segment 13 is maintained at approximately room temperature by slowly flowing room temperature tap water entering the chamber 25, that surrounds the gas tube, at inlet 26 and exhausting to a drain through outlet 27. The Varian flanges 14, 15 and 16 also provide the electrical potential electrodes. The central joint Varian flange 14 is made the system electrical ground potential. The foregoing dimensions are not critical; they are merely representative of a typical operating embodiment.

Electrical discharge is independently maintained in each cooled tube segment. The potential source 26 provides the electrical energy for the glow discharge over the approximately 92 cm length between flanges 14 and 15 in the liquid-nitrogen-cooled segment and potential source 27 provides the electrical energy for the glow discharge over the approximately 85 cm length between flanges 14 and 16 in the room temperature tube segment. It has been found preferable to maintain the discharge in the liquid nitrogen cooled segment

12 with a current flow of approximately 15 ma. The current flow in the room temperature segment is preferably approximately twenty percent lower in magnitude, being typically in the 10 to 15 ma range. While the foregoing enumerated currents are generally considered to be optiminual for the stated gas ratios and tubes of the previously stated dimensions, they are not critical. Obviously, the voltages will vary with tube lengths, and currents with tube cross sectional areas. In addition, some variation will also occur if operation is optimized with different laser gas compositions and pressures than those previously stated. Conventional high voltage power supplies 26 and 27 independently provide these current flows. Conventional high voltage supplies of 5 to 15 kv with series protective and current limiting resistors 28 and 29 are suitable potential sources. The exact voltage of the power supplies are not critical as long as they can supply the approximate current flows previously indicated. Typical voltage values across the discharges may vary from approximately 1 to 2 kv depending on the ratios of the gas constituents and the total gas pressures.

The optical cavity formed between the 10 m radius concave mirror 30, with a 1.6 mm centered circular hole 31, and flat mirror 32 is approximately 263 cm in length. Preferably both mirrors are conventional silver coated or aluminum coated mirrors for extended wavelength reflectivity in the operating wavelengths. The hole-coupled

optical cavity is essentially nonwavelength selective. Generally, the hole-coupled type optical cavity is preferred, however, a partially transparent mirror system, partially transparent at the wavelength involved, may be used. The conventional pressure control system 33 maintains a gas flow of approximately 20 liters per minute (15 to 25 liters per minute is suitable), through the gas tube. The helium, air, and CO gases 34, 35 and 36 from conventional sources are premixed in conventional gas mixing chamber 11 to provide partial pressure ratios of approximately 21/3/1 respectively. The total tube pressure as indicated by gage 37 is preferably about 10 torr.

In a typical operating embodiment of the invention, as set forth in detail in the foregoing, the CO and CO_2 laser lines were measured and identified to be predominently P-branch for both molecules with J = 13-21 of the v, v' = 16, 15 to 7,6 bands for CO, and J = 16, 18, 20, 22 of the 001-100 band for CO_2. A total laser power of approximately 2 watts was generated with substantially equal powers for each wavelength region. The He-Air-CO laser gas mixture did not include CO_2. The CO_2 is formed in the discharge. The amount of CO_2 present, due to the use of normal ambient air as the O_2 source, is negligible since the relative CO_2/CO ratio initially in the tube (before discharge) was approximately 10^{-3}. The formation of CO_2 in the laser tube apparently proceeds by the discharge-initiated dissociation of the CO and air molecules with subsequent

oxidation and recombination to form CO_2 molecules. A reverse reaction must occur with CO_2 reforming CO, probably in a vibrationally excited state. No carbon residue was visually apparent in any embodiments of the apparatus, indicating that the oxidation reactions were essentially complete.

The use of ambient air as the O_2 source does have an effect on the laser action by the reactions involving N_2, N_2O, and the lasing molecules. The N_2 and CO molecules acquire vibrational excitation by inelastic energy exchange with the discharge electrons. The $N_2(v)$ will transfer energy to $CO_2(000)$ producing $CO_2(001)$, and collisionally exchange energy with CO(v) forming CO(v+1) molecules. The $N_2O(000)$ molecules cause $CO_2(100)$ and $CO_2(010)$ deactivation, as well as influencing the $CO_2(001)$ population. The amount of water vapor present in the ambient air source is not critical. Any normal variations may be disregarded in the operation of the apparatus.

The mutual interaction of the He, CO, and CO_2 are the main influences to the laser action. The $CO(v \leq 8)$ formed by the discharge electrons are modified by collisions with other CO(v) molecules. The v-v energy transfer between CO molecules produces partial inversions on $CO(v \geq 8)$, and is the dominating reaction in the CO laser. The CO(v) molecules also resonantly exchange energy with $CO_2(000)$ to produce $CO_2(001)$ molecules. The relaxation rate of the $CO_2(010)$ level is increased by $CO(v \geq 8)$, thereby effectively modifying both

laser actions. The main effect of He is to lower the overall gas temperature, and to influence the $CO_2(001)$ level, but it has little effect upon the CO.

The generation of simultaneous CO and CO_2 laser action is apparently due primarily to the use of a segmented laser tube with different cooling temperatures. It appears that the CO laser radiation resulted from the liquid nitrogen cooled tube segment, while the CO_2 laser radiation resulted from the water cooled tube segment. Laser action from CO alone was achieved with a discharge in the liquid nitrogen cooled segment when the water cooled segment was made inactive (by removal of excitation voltage), and laser action from CO_2 alone was achieved with a discharge in the water cooled segment with the liquid nitrogen cooled segment inactive. These results are interpreted as indicating a requirement for significant oxidation of CO to CO_2, and thermal optimization for each molecule.

It is believed that the foregoing described embodiment of the invention will generally be the preferred embodiment since substantially equal laser output occurs in the two wavelength bands, however the following additional embodiments will be preferred where different ratios of laser powers in the two bands are desired. It has been found that simultaneous laser action at both CO and CO_2 wavelengths (5.2 to 5.9 μm and 9.6 to 10.6 μm, respectively) will occur with a single discharge through both tube segments, i.e., removing the connections from the center flange 14 and using a

single power supply with the Varian flanges 15 and 16 as the electrodes. The polarity is not critical. Generally, the negative potential is also made the system ground. Reversing the direction of gas flow through the device is now preferred, that is, the gas flow from the mixing chamber 11 enters the water cooled tube segment first then flows on through the liquid nitrogen cooled segment. In this embodiment the same total laser power, two watts, results but the ratio of CO_2 to CO power is approximately 3 to 1. Optimum relative partial pressures of the Helium, air, and CO gases in this embodiment are approximately 16 to 1 to 1, respectively, with a total tube pressure of approximately 18 torr. The optimum dc current occurs in the range of 10 to 20 ma. Parameters other than those enumerated are substantially the same as in the previous embodiment.

It was also found that CO_2 to CO laser power ratios of approximately 8 to 1 may be obtained by using a mixture of Helium, air, and CO_2 at pressure ratios of approximately 86 to 2 to 1 respectively with the gas flow entering the water cooled segment first. Approximately the same total power of 2 watts was still obtained. A single discharge potential was used between flanges 15 and 16. The polarity is not critical. Generally the preferred value of current flow is within the range of 10 to 20 milliamperes.

In the foregoing embodiments described in detail, the parameters of relative helium, air, and CO (or CO_2) gas pressures, and tube

currents and tube voltages, were found to be optimum. However, these values are not critical and they may be varied substantially and still obtain laser operation. It was also found that the embodiments would provide laser operation with an ac discharge voltage. The dc discharge, however, is the preferred type of discharge.

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